action of an epistatic or inhibiting factor *I*. Thus the constitution of the Snowflake singles giving rare slender progeny may be *IS'D/is'd* or *DS'I/ds'i*. A serious theoretical difficulty seemed to arise in the apparent necessity for several specific "inhibitors" all giving the same "normal" type, and also for relatively frequent dominant mutations. Perhaps, however, the apparent mutation may usually consist in the development or disappearance of some condition of duplication in one chromosome of the pair concerned. Origin of apparent mutants through duplication of whole chromosomes, as seems to have been demonstrated for a remarkably similar series of mutant forms in *Datura* (Blakeslee, Belling and Farnham, 1920), seems to be precluded in these cases by the evident linkage phenomena.

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THE NEUROMOTOR APPARATUS OF PARAMECIUM

THE discovery of a neuromotor apparatus in *Diplodinium ecaudatum* (Sharp 1) and *Euplotes patella* (Yocom 2) confirmed by Taylor (3) leads me to expect similar conductile fiber systems in other ciliates. This expectation has been met in the

well-known ciliate *Paramecium*. The neuromotor apparatus of this organism consists of fine branching fibers in the periphery and the cytopharynx, converging to the neuromotor center.

In the periphery these fibers are connected to the basal granules of the cilia and also to the trichocysts. From these organelles they may be traced to the neuromotor center (Fig. 1, *n. c.*) located in the endoplasm just anterior to the cytostome. They

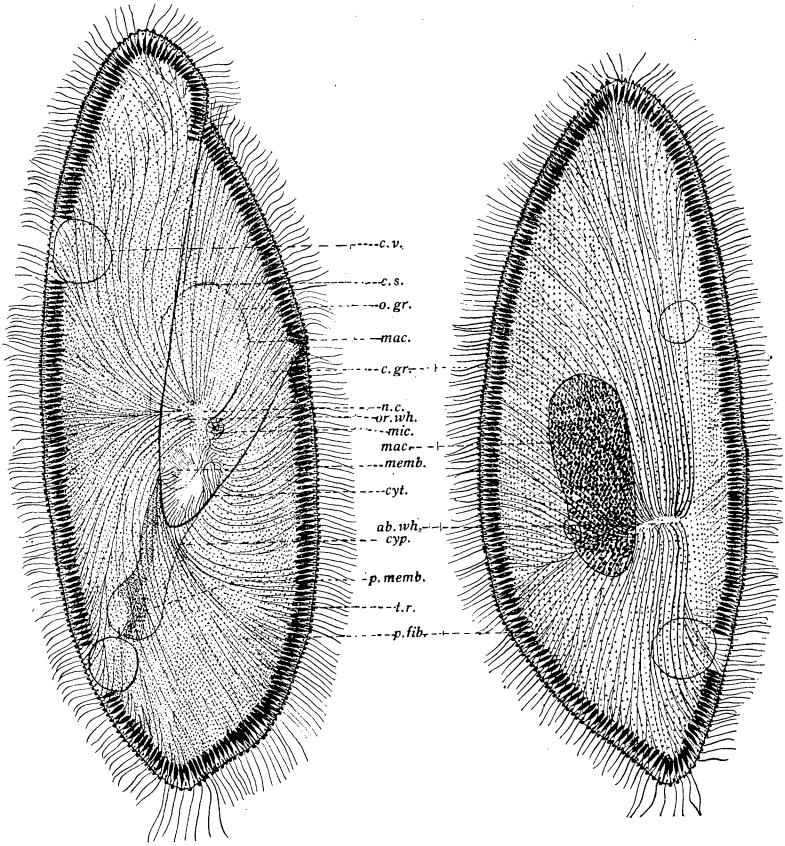

FIG. 1. FIG. 2.

FIG. 1. *Paramecium caudatum*, diagrammatic sketch showing oral whorl of peripheral neuromotor fibers, the neuromotor center, ciliary grooves, trichocyst ridges, ciliary suture, cytostome and cytopharynx with anterior and posterior membranelle zones.

FIG. 2. *Paramecium caudatum*, diagrammatic aboral view, showing aboral whorl of neuromotor fibers.

Abbreviations: *c. v.*, contractile vacuole; *c. s.*, ciliary suture; *o. gr.*, oral groove; *mac.*, macronucleus; *mic.*, micronucleus; *n. c.*, neuromotor center; *or. wh.*, oral whorl; *memb.*, anterior membranelle zone; *cyt.*, cytostome; *ab. wh.*, aboral whorl; *cyp.*, cytopharynx; *p. memb.*, posterior membranelle zone; *t. r.*, trichocyst ridges; *p. fib.*, peripheral neuromotor fibers.

are arranged in whorls, one on the oral side, the other on the aboral side (Fig. 1, *or. wh.;* Fig. 2, *ab. wh.*).

The oral whorl is the more extensive. In the oral groove (Fig. 1, *o. gr.*) the fibers run obliquely caudad to the cytostome where they turn and converge obliquely cephalad to the neuromotor center. From other parts of the oral surface they run in gracefully curved lines directly to the neuromotor center.

The fibers of the aboral whorl converge in a large apex on the right, opposite and slightly posterior to the cytostome. Here they dip into the endoplasm and run direct to the neuromotor center.

The entire periphery of the animal is supplied with the diverging fiber ends of these two whorls. On the left side those of the oral whorl meet those of the aboral whorl about midway between the two sides. On the right the inner ends of the fibers of the oral whorl mingle with those of the aboral whorl near the converging apex of the latter.

Two sets of fibers connect the organelles of the cytopharynx with the neuromotor center. One, a fan-shaped set, runs in the right wall of the cytopharynx to the anterior membranelle zone. The other set consists of two fibers which run from the neuromotor center to the peristomal cilia around the cytostome and meet in the posterior margin. From here they run in the oral side of the cytopharynx and branch profusely into the posterior membranelle zone and the endoplasm. This posterior zone, the cilia of which beat in an opposite direction to those of the anterior membranelle zone, has not been previously described. The cytopharyngeal fibers are heavier than the peripheral fibers and may be seen in living unstained animals under oil immersion.

The trichocysts are arranged with reference to the peripheral neuromotor fibers in whorls. They reach the surface of papillæ which constitute interrupted ridges (Fig. 1, *t. r.*). The cilia, however, spring from longitudinal grooves. The grooves from each side of the oral surface meet in a series of V's, the apices of which lie in a line, the ciliary suture (Fig. 1, *c. s.*) which extends obliquely through this surface from the anterior to the posterior end.

Fibers were found in 2.5 μ sections connected to the basal granules of the cilia and running into the endoplasm. Khainsky (4) also found these fibers and called them ciliary rootlets. They are here interpreted as the ends of the peripheral neuro-

motor fibers. Similar fibers have been found connected to the inner ends of the trichocysts.

From the foregoing it is seen that the neuromotor system of *Paramecium* consists of fibers running from the neuromotor center to the membranelle of the cytopharynx and also from the same center to the basal granules of the peripheral cilia and to the trichocysts. Its morphology suggests that it is conductile in function adapted to coordinate the movements of the peripheral cilia and the cytopharyngeal membranelles.

The peripheral fibers were discovered in whole mounts fixed, stained and dehydrated in centrifuge tubes. The best stain was Heidenhain's iron alum hæmatoxylin. They were not seen with this stain when the animals were attached to the slide by egg albumen. However, contrary to Neresheimer (5), the distal fiber ends were sometimes seen in such preparations when Mallory's triple connective tissue stain was used. Complete cytological details were worked out only from the hæmatoxylin preparations.

This idea of staining non-distorted animals in centrifuge tubes resulted from micro-injection studies. It was found that animals survived such operations only when isolated in rounded drops. Blisters invariably formed when they were held flattened to the cover by water-glass surface tension (Taylor 3). An apparatus embodying the principle of Taylor's micro-injection pipette (Taylor 6) was constructed by means of which isolation was accomplished in such small drops that only a very limited movement of the animal was possible. To secure rounded drops the cover was coated with a thin film of oil as described by Barber (7).

Three kinds of experimental methods in attempting to demonstrate that the fibers are conductile were carried out as follows:

Grübler's methylene blue which stains nerve fibers in metazoan tissue (Wilson 8) gave negative results when injected into *Paramecium*.

An antero-posterior gradient was demonstrated as follows: The organisms were isolated in 4 per cent. to 6 per cent. alcohol, 1/10 per cent. nicotine, 1 per cent. antipyrin, or 1 per cent. morphine hydrochlorate. In all cases the anterior cilia ceased beating at least ten seconds earlier than the posterior cilia and those of the cytopharynx. The animals did not disintegrate as do planarians and annelid worms in these solutions so that

the physiologically anterior end (Child 9) could not be determined. But the antero-posterior gradient is what one would expect in animals possessing fibers which conduct efferent impulses (Tashiro 10).

Contrary to Neresheimer (5) the animals are narcotized in these solutions.

Micro-dissection experiments showed that the coordination of movement of the cytopharyngeal membranelles is interrupted when the neuromotor fibers are cut. Those posterior to the cut beat slower and with smaller amplitude than those anterior to it. Extensive destruction of structures in the region of the neuromotor center or motorium destroyed coordinated movement of the peripheral cilia. In one case in animals isolated in gelatine four zones of cilia were seen. Those of one side beat in opposite directions to those of the other.

CONCLUSIONS

A complex fibrillar apparatus has been differentiated in *Paramecium*. It connects the membranelles of the cytopharynx and the peripheral cilia and also the trichocysts with the neuromotor center. Therefore, the morphology of this system suggests that it is conductile. Experimental data strengthens this morphological evidence; first, because the antero-posterior gradient that exists here is that which would be expected in an animal possessing a complex system of fibers which conduct efferent impulses from the anterior end to the neuromotor center; second, the micro-dissections indicate that coordinated movement of the cytopharyngeal membranelles is interrupted when neuromotor fibers are severed and coordinated movement of the peripheral cilia is interrupted when the neuromotor center is destroyed.

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A NEW MUTATION IN THE HOUSE MOUSE[1]

A NEW and distinct mutation in mammals is not a frequent occurrence, and therefore the record of a recent dilute form of the house mouse, allelomorphic to color and albinism, is perhaps justifiable.

The infrequency of mutations in mammals may be due to greater stability of the germ plasm than in such forms as insects, for example, *Drosophila;* or may be due to our lack of opportunity for examining as large a population of mammals as of insects; or possibly may be due to a more frequent lethal effect associated with mutations in mammals. Whatever the cause is, a tendency toward similar mutations in closely related groups of mammals is apparent and suggestive. The fact that a given type of mutation has occurred in one group is some promise that a corresponding mutation is possible and may occur in a closely related group. The pink-eyed mutation (giving PINK-eyed colored varieties) in mice has been known for some time. A similar mutation in rats was described recently (Castle, '14).[2]

[1] Paper No. 17, Genetics Laboratory, Illinois Agricultural Experiment Station.

[2] Castle, W. E., 1914, AM. NAT., Vol. 48, p. 65.